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4.1.1 Passive Solar Design

Passive solar systems make use of natural energy flows as the primary means of harvesting solar energy. Passive solar systems can provide space heating, cooling-load avoidance, natural ventilation, water heating, and daylighting. This section focuses on passive solar heating, but the other strategies also need to be integrated and coordinated into a whole-building design. Passive solar design is an approach that integrates building components—exterior walls, windows, and building materials—to provide solar collection, heat storage, and heat distribution. Passive solar heating systems are typically categorized as sun-tempered, direct-gain, sunspaces, and thermal storage walls (Trombe walls). In most U.S. climates, passive solar design techniques can significantly reduce heating requirements for residential and small commercial buildings.

Opportunities

New construction offers the greatest opportunity for incorporating passive solar design, but any renovation or addition to a building envelope also offers opportunities for integration of passive methods. It is important to include passive solar as early as possible in the site planning and design process, or when the addition or building is first conceived. Ideally, an energy budget is included in the building design specifications, and the RFPs require the design team to demonstrate their commitment to whole-building performance and their ability to respond to the energy targets. This commitment is emphasized during programming and throughout the design and construction process.

For retrofit projects, consider (1) daylighting strategies, such as making atria out of courtyards or adding clerestories, along with modification of the electric lighting system to ensure energy savings; (2) heat control techniques, such as adding exterior shades or overhangs; and (3) using passive solar heating strategies to allow modification of HVAC systems—perhaps down-sizing if the passive strategies reduce energy loads sufficiently.

Many buildings in the Federal inventory have passive features because they were built before modern lighting and HVAC technologies became available. When renovating older buildings, determine whether passive features that have been disabled can be revitalized.

Technical Information

Terminology. *Sun tempering* is simply using windows with a size and orientation to admit a moderate amount of solar heat in winter without special measures for heat storage. *Direct gain* has more south-facing glass in occupied spaces and thermal mass to smooth out temperature fluctuations. A *Trombe wall* puts the thermal mass (e.g., tile floors) directly behind the glazing to reduce glare and overheating in the occupied space. A *sunspace* keeps the glass and mass separate from the occupied space but allows for the transfer of useful heat into the building by convection or a common mass wall; temperatures in a sunspace are allowed to fluctuate around the comfort range.

Highlight passive solar as a project goal. Many agencies, including GSA and DOD, already encourage the use of passive solar design and renewables in new construction and major renovation. A good general project goal is "to produce a beautiful, sustainable, cost-effective building that meets its program, enhances productivity, and consumes as little nonrenewable energy as possible, through the use of passive solar design, energy efficiency, and the use of other renewable resources."

Incorporating energy performance goals into the programming documents conveys the seriousness of energy consumption and the use of passive solar as a design issue. For small offices, warehouses, and other smaller projects—10,000 sq ft (930 m^2) or less—facility managers or their contractors can develop energy budgets easily using software such as *Energy-10*. For larger multi-zone projects (for example, laboratories or high-rise office buildings), national average energy consumption data by building type can be cited as targets to be exceeded, or more complex analyses can be run by consultants. The building program should describe an articulation that allows passive solar strategies to be effective (for example, large multistory core zones are hard to reach with passive solar). The building program should also describe requirements, such as privacy and security, that may influence the type of passive solar heating system that can be used.

Thirty to fifty percent energy cost reductions below national averages are economically realistic in new office design if an optimum mix of energy conservation and passive solar design strategies is applied to the building design. Annual savings of $0.45 to $0.75 per sq ft ($5 to $8/m^2) is a reasonable estimate of achievable cost savings.

Passive solar design considers the synergy of different building components and systems. For example:

- Can natural daylighting reduce the need for electric light?
- If less electric light generates less heat, will there be a lower cooling load?
- If the cooling load is lower, can the fans be smaller?

- Will natural ventilation allow fans and other cooling equipment to be turned off at times?

Passive solar design is often more challenging than designing a mechanical system to accomplish the same functions. Using the building components to regulate temperature takes a rigorous analytical approach to optimize performance while avoiding such problems as overheating and glare.

> Buildings properly designed using passive solar systems and strategies are generally more comfortable for the occupants, resulting in productivity benefits that are great relative to the building cost.

Generic design solutions or rules of thumb are of limited value. Rules of thumb may be useful in anticipating system size and type, but only early in the design process. Computer simulation provides much more accurate guidance because of the complexity of system combinations and interactions. Some of the variables involved include:

- Climate (sun, wind, air temperature, and humidity);
- Building orientation (glazing and room layout);
- Building use type (occupancy schedules and use profiles);
- Lighting and daylighting (electric and natural light sources);
- Building envelope (geometry, insulation, fenestration, air leakage, ventilation, shading, thermal mass, color);
- Internal heat gains (from lighting, office equipment, machinery, and people);
- HVAC (plant, systems, and controls); and
- Energy costs (fuel source, demand charges, conversion efficiency).

The Trombe wall at the NREL Visitors Center in Golden, Colorado, provides passive heating and daylighting to the exhibit hall. Photo: Warren Gretz

An hourly simulation analysis combines all of these parameters to evaluate a single figure-of-merit, such as annual energy use or annual operating cost.

The integrated interaction of many energy-efficient strategies is considered in passive solar design. These include: passive solar heating, glazing, thermal mass, insulation, shading, daylighting, energy-efficient lighting, lighting controls, air-leakage control, natural ventilation, and mechanical system options such as economizer cycle, exhaust air heat recovery, high-efficiency HVAC, HVAC controls, and evaporative cooling.

> Passive solar design is an integrated design approach optimizing total building performance rather than a single building system. This is the key to "green building" design.

Cost and technical analyses are conducted at the same time in passive solar design to optimize investments for maximum energy cost savings. It is rarely feasible to meet 100% of the building load with passive solar, so an optimum design is based on minimizing life-cycle cost: the sum of solar system first-cost and life-cycle operating costs. *Means Assemblies Cost Data* is a good source of cost information for thermal storage walls (Trombe walls) and other selected strategies. It is difficult to separate the cost of many passive solar systems and components from other building costs because passive solar features serve other building functions—e.g., as windows and wall systems.

References

Olgyay, Victor, *Design with Climate: Bioclimatic Approach to Architectural Regionalism*, Princeton University Press, Princeton, NJ, 1963.

Watson, Donald, and Kenneth Labs, *Climatic Design: Energy-Efficient Building Principles and Practices*, McGraw-Hill, New York, NY, 1983.

Designing Low-Energy Buildings, Sustainable Buildings Industry Council, Washington, DC, 1997.

Means Assemblies Cost Data 2000, R. S. Means Company, Inc., Kingston, MA, 2000.

Contacts

FEMP offers a course on passive solar design, *Designing Low-Energy Buildings.* Call (800) DOE-EREC (363-3732) for course information.

Sustainable Buildings Industry Council (SBIC), 1331 H Street, NW, Suite 1000, Washington, DC 20005 (202) 628-7400; www.sbicouncil.org. SBIC sponsors workshops on low-energy building design and markets *Energy-10*, the software developed by NREL to aid in the evaluation of passive measures in residential and small, single-zone commercial buildings.